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Passage Key Inlet, Florida; CMS Modeling and Borrow Site Impact Analysis

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PURPOSE: This Coastal and Hydraulics Engineering Technical Note (CHETN) describes the use of a nested Coastal Modeling System (CMS) model for Passage Key Inlet, which is one of the connections between the Gulf of Mexico and Tampa Bay in southwest Florida (Figure 1). CMS was used to examine any potential impacts of a proposed borrow site on tidal currents, wave climate, or wave-driven sediment transport at Passage Key Inlet. This analysis resulted in issuing a new Florida Department of Environmental Protection (FDEP) permit to award a Flood Control and Coastal Emergency (FCCE) beach nourishment contract in the wake of Tropical Storm Debby which occurred in June 2012. Active projects existing in this region include the Pinellas County Shore Protection Project (SPP), Tampa Harbor Deepening Project, Manatee County SPP at Anna Maria Island, the City of Sarasota SPP at Lido Key, Sarasota County SPP at Venice Beach, and a number of federally authorized channels. Local projects exist at Longboat Key and Siesta Key. This study was supported by the U.S. Army Corps of Engineers (USACE) Jacksonville District (SAJ) and the USACE Engineer Research and Development Center (ERDC) through the USACE Regional Sediment Management (RSM) Program.

INTRODUCTION: Anna Maria Island is a 7.5-mile-long barrier island located directly south of Tampa Bay and is the only barrier island located entirely within Manatee County. The island is located 40 miles south of the City of Tampa and 7 miles west of the City of Bradenton in Manatee County, FL. Historic datasets available for the geologic investigation were re-evaluated and analyzed to assess the volume of material remaining in the existing 2011 ebb shoal borrow site. Based on pre-and post-construction surveys, it was anticipated that a maximum of 400,000 cubic yards (yd³) of material remained within the 2011 ebb shoal borrow site. However, some of this material might not have been easily accessed by a dredge and thus might not have been available for the proposed beach nourishment project. Therefore, additional investigations were conducted to locate sediment for the beach nourishment project. The 2011 borrow site was the only then-allowed sediment borrow source for the Manatee County SPP at Anna Maria Island, and finding an acceptable expansion of the site for additional sediment was critical for obtaining a FDEP permit for the emergency beach nourishment. It was proposed to expand the existing ebb shoal borrow site to obtain 2.8 million yd³ (Myd³) for the Manatee County SPP at Anna Maria Island.

CMS was run both with and without sediment removal from the expanded borrow site to understand the effects of additional sediment removal on tidal currents, wave climate, and/or wave-driven sediment transport at Passage Key Inlet. It was determined that the first option of removing 2.8 Myd³ from the borrow site could potentially adversely affect sediment transport due to wave action. This volume was subsequently reduced to a 1.75 Myd³ expansion of the borrow site.

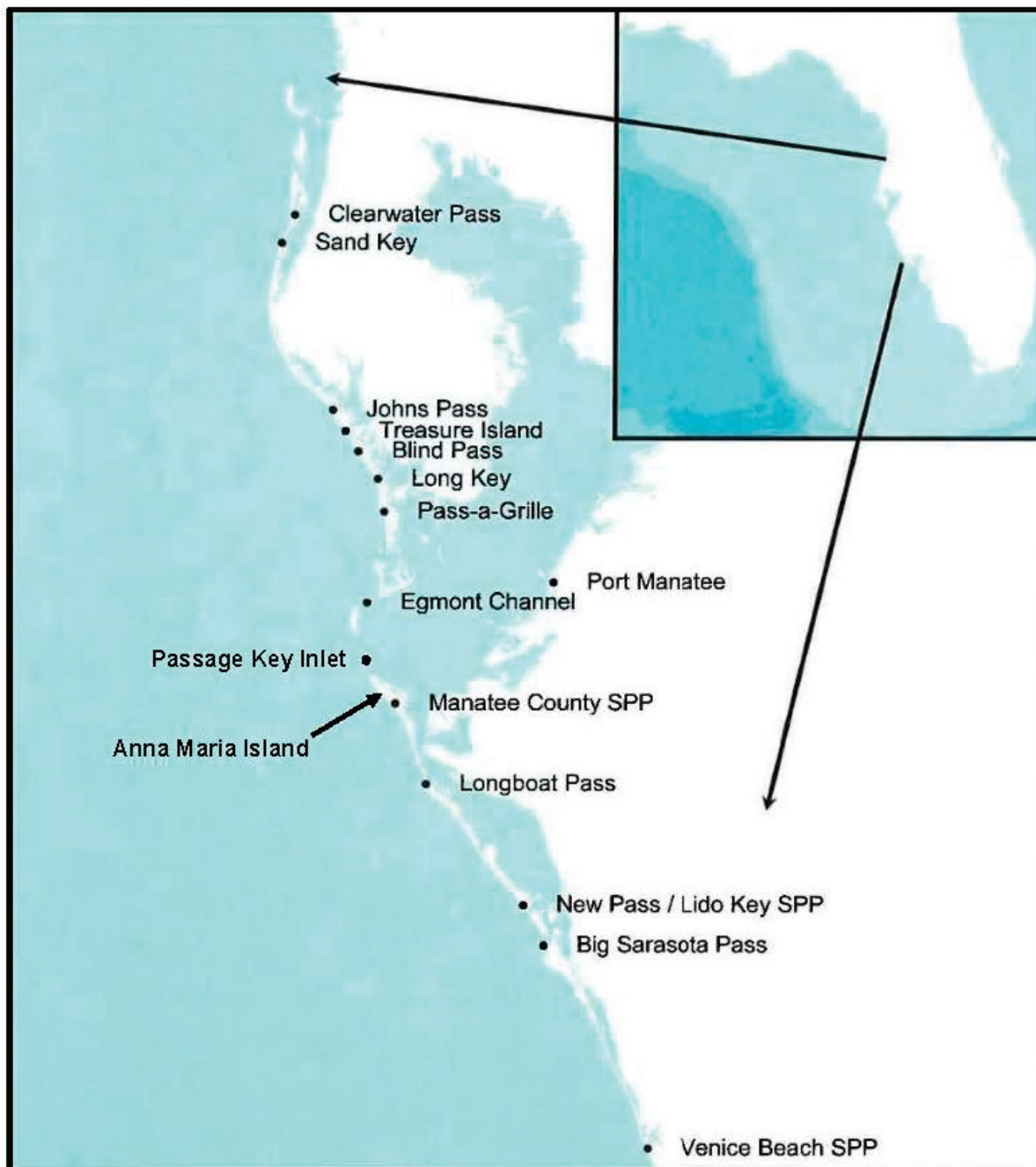


Figure 1. Active USACE Jacksonville District (SAJ) projects in Pinellas, Manatee, and Sarasota Counties, FL.

METHOD: The CMS is a product of the Coastal Inlets Research Program (<http://cirp.usace.army.mil>) managed at ERDC. CMS is composed of two models, CMS-Flow (Buttolph et al. 2006; Wu et al. 2011) and CMS-Wave (Lin et al. 2008). CMS-Flow is a finite-volume, depth-averaged model that can calculate water surface elevation, flow velocity, sediment transport, and morphology change (Camenen and Larson 2007). Within CMS, CMS-Flow is coupled with CMS-Wave, which calculates spectral wave propagation including

refraction, diffraction, reflection, shoaling, and breaking and also provides wave information for the sediment transport formulas.

The CMS was used to examine the 4-month time period between 1 March and 1 July 2007. National Oceanic and Atmospheric Administration WAVEWATCH III data were obtained to input wave conditions for this period (<http://polar.ncep.noaa.gov/waves/ensemble/download.shtml>). Tidal harmonic constituents drove the offshore boundary condition. Current and wave interactions were included in the model. Two borrow site conditions were developed for the CMS grid: (1) the initial 2.8 Myd³ borrow and (2) the redesigned 1.75 Myd³ borrow after it was determined the 2.8 Myd³ borrow might adversely affect sediment transport due to wave action. CMS was run for approximately 120 diurnal tidal cycles with the wave conditions that existed for the 4-month modeling time period.

RESULTS

Tidal currents. Tidal currents were compared for flood and ebb tides for the condition in which 2.8 Myd³ of sediment were extracted from the ebb shoal in the configuration specified in Figures 2a and 2b, and for the condition where no action took place (i.e., the ebb shoal was not dredged). Current velocities for flood and ebb tides are shown in Figures 2a and 2b, respectively. For both conditions with and without borrow, velocities decreased significantly during ebb tide before reaching the borrow site. The site is approximately 5,000 feet (ft) offshore at a distance where tidal currents become insignificant. Flood and ebb currents for both with and without borrow conditions were subtracted from each, resulting in zero, meaning that the flow fields were identical for both scenarios and no flow alterations had occurred due to the modified morphology from the removal of this 2.8 Myd³ of material. It was concluded that the 2.8 Myd³ borrow would not affect tidal currents, most likely due to its distant offshore location.

It was further concluded that, based on CMS results of this investigation, the proposed dredging would not alter tidally driven sediment transport to the ebb and flood shoals.

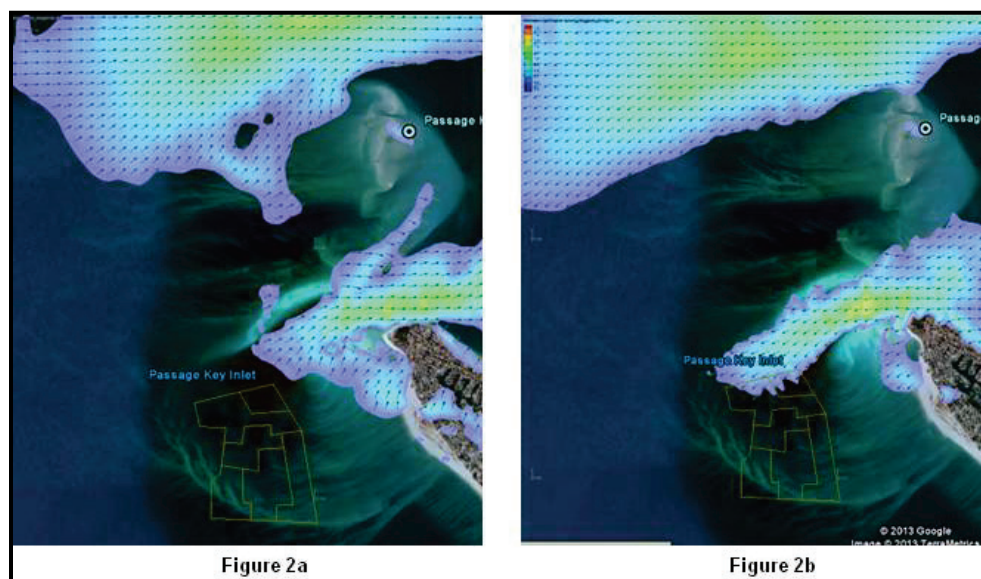


Figure 2a. Flood currents. Figure 2b. Ebb currents. North is up in all figures.
(2.8 Myd³ removed from proposed borrow site, light green).

Wave climate. The change in wave height at the borrow site was examined under conditions of no borrow and both 1.75 Myd³ and 2.8 Myd³ borrow. Figure 3a shows the difference in wave height between the 2.8 Myd³ borrow and no borrow. Figure 3b shows the difference in wave height between a 1.75 Myd³ borrow and no borrow. Overall, differences in wave height were extremely localized and were between +/- 1.0 ft (0.3 meters [m]). The *maximum* change in wave height for the 1.75 Myd³ borrow (Figure 3b) was a lesser magnitude and smaller footprint than changes in wave height for the 2.8 Myd³ borrow (Figure 3a). The effect on the wave climate was further removed from the shoreline for the 1.75 Myd³ option than for the 2.8 Myd³ option. It was concluded that the borrow site would have insignificant effects on the wave climate of Passage Key Inlet for both the 1.75 Myd³ borrow and the 2.8 Myd³ borrow.

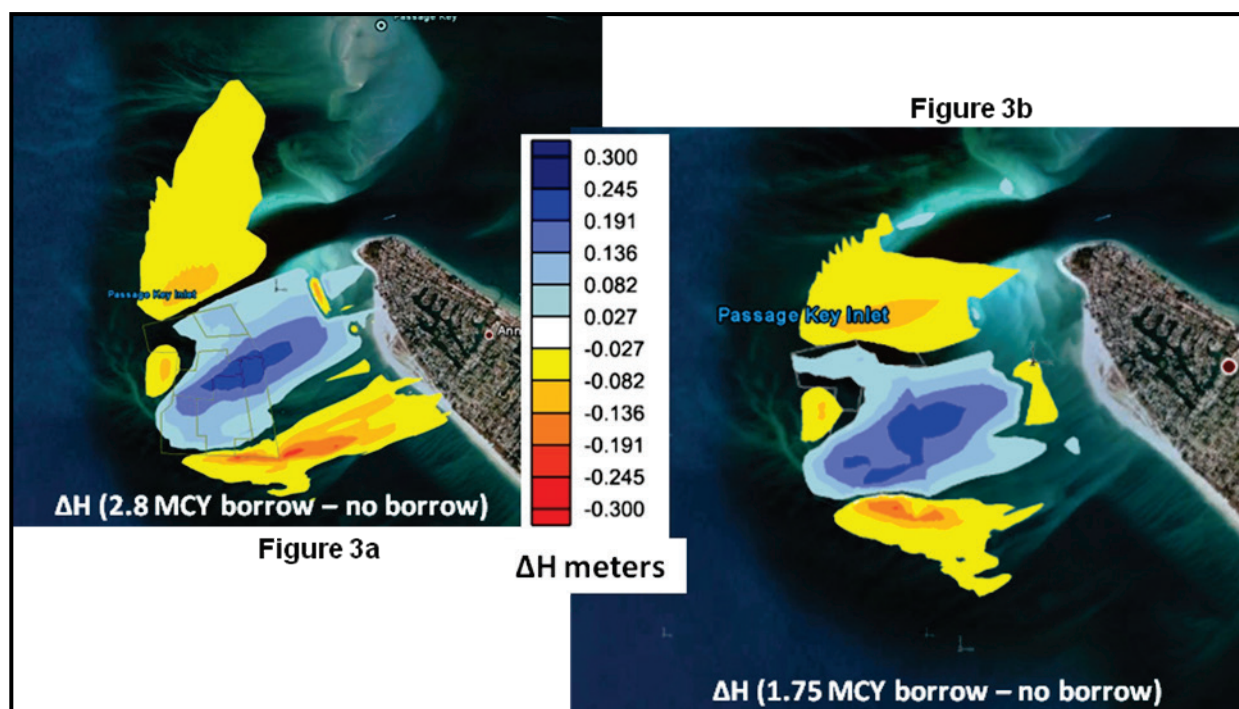


Figure 3a. Difference in wave height (ΔH meters); north is up in all figures. (2.8 Myd³ borrow–no borrow).
Figure 3b. Difference in wave height (ΔH meters); (1.75 Myd³ borrow–no borrow). (Borrow site for 2.8 Myd³ in light green, Figure 3a. Borrow site for 1.75 Myd³ in light green, Figure 3b).

Wave-driven sediment transport. Wave driven currents are generated by gradients in momentum flux due to the decay of incident waves as they break, either in the surf zone or over a shoal. Because momentum is conserved, this energy is transferred both to the mean flow and to the bed as friction. Wave currents driven by the momentum flux due to wave breaking provide the flow mechanisms responsible for sediment transport and the resulting coastal morphology. Radiation stresses (S_{xx} and S_{yy}) were exported from CMS-Wave and plotted to examine differences in the momentum flux with and without borrow sediment removal.

Figures 4a, 4b, and 4c show that the difference (Δ) in radiation stress (S_{yy} only, the cross-shore component of the radiation stress along the primary wave transport pathway) for the case of the 2.8 Myd³ borrow was significant and could potentially affect sediment transport due to wave action. Figure 4c is the radiation stress difference (Δ) between no borrow (Figure 4b) and 2.8 Myd³ borrow (Figure 4a). Because of the potential interruption of the sediment transport

pathway along the outer shield of the ebb shoal, the borrow site was redesigned to remove only 1.75 Myd³ of sediment and to avoid the most southwestern portion of the shoal. Figures 5a and 5b show that the difference (Δ) in radiation stress along the primary pathway for the case of the redesigned 1.75 Myd³ borrow site was negligible and would not affect wave driven transport along this pathway. (The computational coordinate system is oriented with x in the alongshore direction and y in the cross-shore direction of wave propagation.)

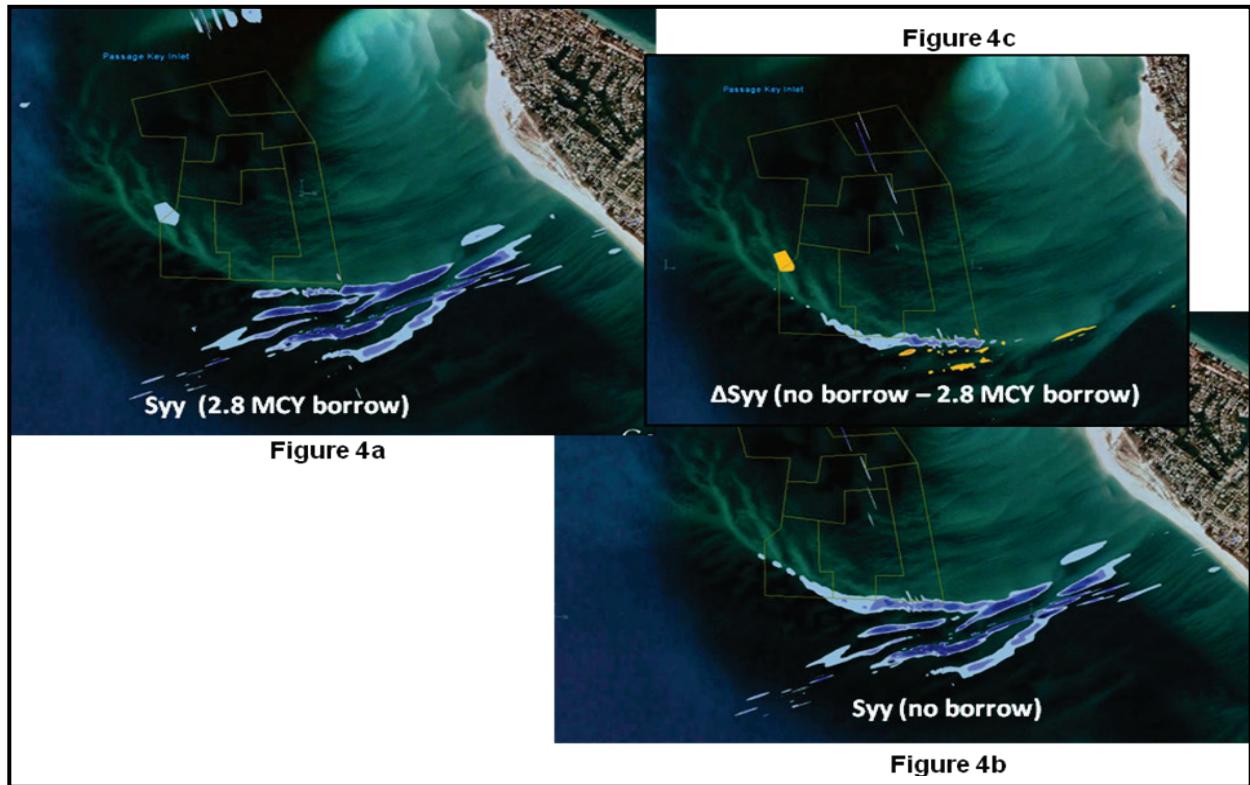
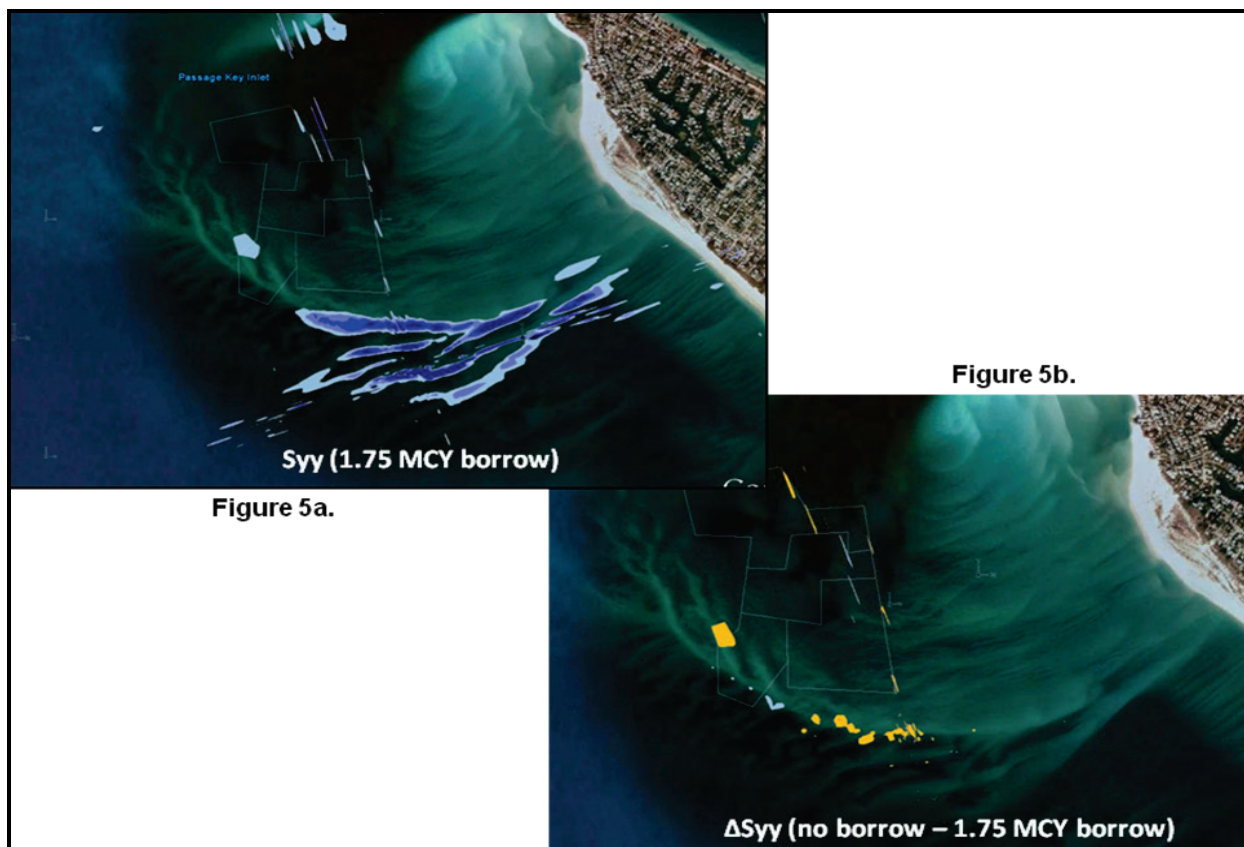


Figure 4a. Radiation stress, 2.8 Myd³ borrow, predominant sediment transport pathways. Figure 4b. Radiation stress, no borrow, predominant sediment transport pathways. Figure 4c. Radiation stress difference (Δ) between no borrow and 2.8 Myd³ borrow. North is up in all figures. (Pathway along outer edge of 2.8 Myd³ borrow site is interrupted relative to the no-borrow condition.)

DISCUSSION: CMS was used to examine the potential impact of a proposed borrow site for Passage Key Inlet using the nested grid that had previously been developed through the RSM program. It was found that the ebb shoal at Passage Key Inlet could be mined for sediment using a modified dredging template that would not interrupt wave-driven sediment transport. Because the location of the borrow site was well enough offshore, CMS-Flow model results indicated that flood and ebb tidal currents would not be affected by the borrow site.



It was determined through CMS-Wave, however, that wave-driven sediment transport along the outer shield of the ebb shoal could be affected. (This determination was based upon radiation stress gradients and not upon sediment transport modeling.) Therefore, the original 2.8 Myd³ borrow site was modified in size and plan form to be 1.75 Myd³. Subsequent CMS model runs demonstrated that the wave-driven sediment transport pathway along the outer shield of the ebb shoal would not be interrupted using the redesigned 1.75 Myd³ borrow site option.

CONCLUSIONS: CMS modeling of both with and without project bathymetry indicated that the proposed 1.75 Myd³ borrow would induce minimal impact to tidal currents, wave climate, and wave-driven sediment transport across the majority of the study site. Based on results of modeling presented in this CHETN, it was concluded that the proposed 1.75 Myd³ borrow would have minimal impacts to sediment transport processes. Any impacts would be localized and centered on the previously accretional beaches and therefore were not considered a risk to the overall function of the north Anna Maria Island beach and Passage Key Inlet system. The regional and nested CMS models that had previously been developed through the RSM program were used to provide assurances to the FDEP of no negative impact to obtain a permit for FCCE work in the wake of Tropical Storm Debby that occurred in June 2012. The project was constructed between December 2013 and April 2014.

In addition to the Federal project, the permit also provided sediment for the county project at Coquina Beach. The development and approval of a new borrow site was a crucial piece toward having a project complete and ready for award. Once the CMS modeling results were obtained and presented to FDEP, this information was used to complete National Environmental Policy Act and cultural resources consultations. This project progressed from a general concept to a complete and constructible project design within 7 months. Tools available to the RSM program provided comprehensive results to ensure that dredging the borrow site could be performed to the most practicable extent possible while inducing no adverse impacts to the coastal system. The tools also proved to be monumental in executing an emergency beach nourishment contract and in maximizing RSM principles to place sand on the beach.

ADDITIONAL INFORMATION: This Coastal and Hydraulics Engineering Technical Note (CHETN) was prepared by Kelly Legault and Sirisha Rayaprolu, U.S. Army Engineer District, Jacksonville (SAJ). Funding for this study was provided by the USACE Regional Sediment Management (RSM) Program, a Navigation Research, Development, and Technology Portfolio program administered by Headquarters USACE. Additional information pertaining to the RSM Program can be found at the RSM website <http://rsm.usace.army.mil>.

Questions regarding this CHETN may be addressed to Kelly R. Legault (Kelly.R.Legault@usace.army.mil), SAJ Senior Coastal Engineer, Engineering Division. Additional information pertaining to the RSM Program can be obtained from the USACE RSM Program Manager, Linda S. Lillycrop (Linda.S.Lillycrop@usace.army.mil).

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